Electronically tunable mirror with surface plasmons

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ABSTRACT

Surface plasmon tunable filter is a new technology under development at Jet Propulsion Lab. Th is technology can be used to b uild a tunable mirror. When a white light is incident on a metal/110 material interface, in certain condition, surface plasmon waves can be excited at one metal/l;O material interface; those photons in surface plasmon resonance wavelength range will be converted into the energy of free electrons in the metal. When using rhodium or nickel as the metal, the bandwidth of surface plasmon resonance can cover all visible spectrum. This surface plasmon resonance depends on the dielectric constants of both the metal and the EO material, If a voltage is added on the EO material to change its dielectric constant, the reflectivity of the interface will be able to change from less than 0.50/0 to over 80%.

Keywords: electro-optics, tunable mirror, surface plasmon, light modulator.

White light modulator has wide applications for imaging technologies. The conventional approaches arc using liquid crystal light modulator with crossed polarizers or using digital tunable mirrors. Here 1 report a new technology of a white light modulator based on surface plasmon technology.

The surface plasmon has been studied since the 1960's. It can be described as a collective oscillation in electron density at the interface ofa metal and a dielectric. At surface plasmon resonance, the re flected light vanishes. This resonance is referred to as attenuated total reflection, and is dependent upon the dielectric constant of both the metal and the dielectric. If an electro-optical (EO) material is used as the dielectric and a voltage is applied to change the surface plasmon resonance condition, the reflected light can be modulated[1]. A surface plasmon laser light modulator with a contrast ratio greater than 100:1 has been reported[2].

If we consider the surface plasmon light modulator in the frequency space, the photons at surface plasmon resonance will be absorbed and the photons out of the resonance will be totally reflected. If a voltage is applied on the EO material, the index of refraction of the EO material will change, the surface plasmon resonance frequency will change, therefore the reflection spectrum can be controlled by the applied voltage, and an electronically tunable color filter is formed[3]. A surface plasmon tunable color filter has being developed in JPL[456]. It can replace the color wheel for projection displays, and it can be employed for a monochrome liquid crystal panel to generate a full color image.

The bandwidth of a surface plasmon tunable filter depends on the property of the metal film. The dielectric constant ofa metal has real part and imaginary part, generally speaking, the imaginary will determine how wide the bandwidth of the surface plasmon resonance will be. For silver film, because it has a very small imaginary part of its dielectric constant, the surface resonance is relatively narrow, around 30 nm. If metals with bigger imaginary part, for example Rh, Ni, or Pt, are used as the metal film, then surface plasmon resonance can become so wide that it will cover all the visible spectrum, in other words, all of the visible light will be absorbed by surface plasmon resonance. When the surface plasmon resonance is changed by change the dielectric constant of the dielectric material or change the incident angle, a white light can be modulated.

The experiment sample was prepared by thermally evaporating two layers, 10 nm Al plus 5 nm Rh onto a 60(' SF6 glass prism A 50 nm MfF2 layer was then evaporated at a 50° oblique angle ofl'the normal onto the metal film as the liquid crystal alignment layer. The same alignment was evaporated onto an ITO glass plate as the substrate. The cell was assembled with alignment directions parallel, with 4 μm spacers, and filling was capillary action with 111,009 liquid crystal (Merck).

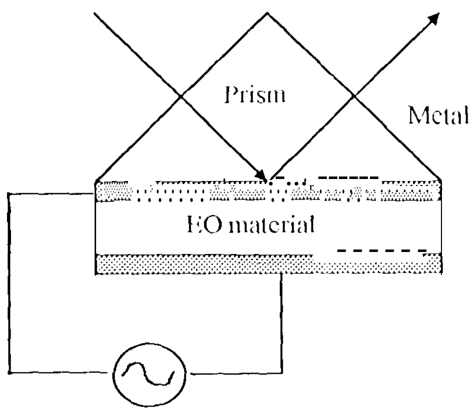

Fig. 1 Experimental set up of surface plasmon white light modulator

The experiment setup of surface plasmon tunable filter is shown in Fig. 1. When a p-polarized white light is incident on the metal/liquid crystal interface through the coupling prism, a surface plasmon wave can be excited, the photons in the surface plasmon resonance will be taken out from the reflected spectrum. Because the AI -Rh metal film has a wide surface plasmon resonance, all visible photons will be absorbed. When a voltage is applied on the liquid crystal, the index of the liquid crystal will change, the surface plasmon resonance will shift out of visible range, and reflected light will resume. The experimental result is shown in Fig. 2, here the dots arc experimental data and the solid curves are theoretical calculations, When a p-polarized white light was incident on this device at zero voltage, the surface plasmon resonance coveted all of the spectrum range, no visible light was reflected. When a 20-v voltage was applied, the surface plasmon resonance shifted to IR range, and some of light was reflected with reflectivity about 25°/0. When the voltage increased to SO-V, the surface plasmon resonance shifted further from the visible, and the reflectivity reached about 50°/0.

The experiment result has shown a contrast ratio of 50:1 and a maximum reflection of 50°/0. It agrees with the theory, but tile maximum reflection from the experiment only reaches 500/0 instead of over 800/0 as the theory predicted. This can be explained as the non-uniformity of the liquid crystal alignment,; because the anchoring force of the liquid crystal is not uniform, when a voltage is applied, the index of liquid crystal in this experiment is not a single value but a mixture of different values. If a better alignment is applied, this surface plasmon white light modulator should be able to reach a contrast ratio over 200:1 with maximum reflection over 80%.

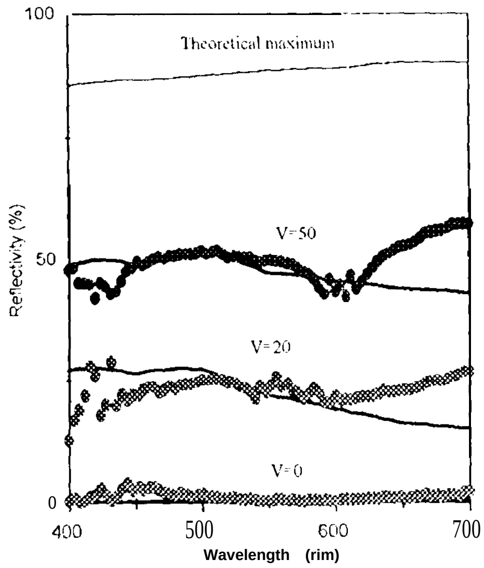

Fig.2 Experiment result compare with theory.

"1'bough liquid crystal material was used in this experiment, the liquid crystal material can be replaced by other solid state EO materials, such as KDP, KTP, EO polymers, organic crystal and organic salts, If a solid state material is used, the surface plasmon white light modulator can reach very fast modulation sped.

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